

# *FlightLinux*



*Free Software in Space - the NASA Case*  
*Software Livre 2002*  
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## Disclaimer

The information presented does not necessarily represent NASA, Goddard Space Flight Center, or QSS policy or opinion.





# *Agenda*



- Project Description
- The Linux Operating System
- Porting Linux to Spacecraft Computers
- Benefits
- Related Research
- Status
- Challenges
- Where is this going?



# ***FlightLinux Project***



- Selected by NASA in May 2000 as a funded project.
- Government-Industry team:
  - NASA/GSFC
  - QSS Group, Inc.
- Principal Investigator: Pat Stakem, QSS Group, Inc.
- Partners:
  - Surrey Space Technology Ltd. (UK)



# *Why Linux?*



- Open source
  - Flexible
  - Extendable
  - Free
- Supports multiple target platforms
- Supports networking which enables multiprocessing
- Commonality with ground platforms - easy to migrate applications
- Real-time extensions being defined
- Large experience base to draw on



# *Open Source Approach*



- Spirit of the GNU Public License - GPL - for open source code.
- FTP site will contain the source code for downloading (subject to export approval)
- Code will be accepted for inclusion - People want to work on this!
- The FlightLinux Project will maintain the configuration-controlled official version.



# ***Benefits***



- Onboard LAN
  - FireWire/SpaceWire
  - 1553 Master/Slave
  - 10/100-Base-T
- Onboard file system, in the bulk memory
- Onboard Java applets, via JVM
- IP to and on the spacecraft
- Onboard web page serving



## *The OES Sensor Web*



- FlightLinux enables NASA's Office of Earth Science Sensor Web
  - Internet connectivity among constellations of Earth orbiting satellites.
  - Commonality of ground and space-based environments for ease of application migration.
- More efficient gathering of data and dissemination of information





# *File System in bulk memory*



- Traditionally, secondary data storage on spacecraft has been tape recorders.
- Rotating magnetic media introduces complications
- Now, with the use of bulk dram, it is still treated and managed as a tape recorder.
- Linux imposes a file system on the bulk memory
- model: the flash file system (ffs), with the RAID model.



## ***Related Research***



- Posix-compliant flight software
  - GSFC ongoing
- End-to-end IP; IP-to-the-spacecraft; mobile IP
  - Omni Project
- Java-onboard
  - algorithm migration demonstrated
- Onboard networked file systems
- Beowulf - distributed processing



## ***Related Research The OMNI Experience***



- IP-to-the-Spacecraft
  - Demonstrated May/June 2000
- UoSat-12 spacecraft
  - 80386EX onboard computer, 4 megabytes
  - custom operating system, with TCP/IP stack
- Demonstrated functionality
  - Ping
  - FTP up & down



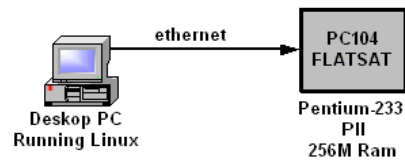
# ***Related research- onboard algorithms***



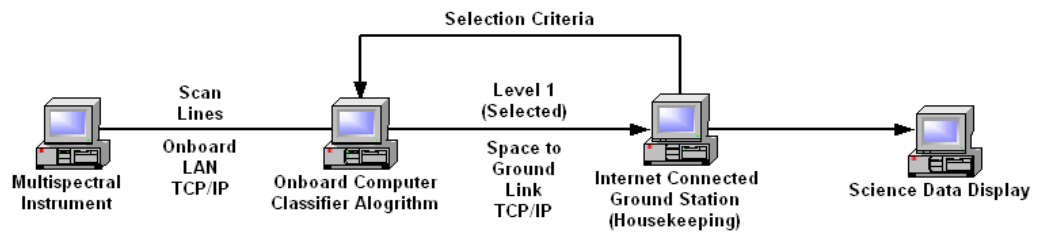
- FlatSat (Omni Project)
  - 233 MHz Intel-based processor
  - embedded system, PC-104 bus, Linux
- Multispectral image classification algorithm
  - implemented in Java, 7 Megabyte footprint
  - 70-90% data downlink reduction (demonstrated 1/2001)
- Onboard LAN connected instrument
  - TCP/IP over 10Base-T
  - simulated scanning instrument, Landsat MSS-class
- Downlink
  - TCP/IP over 10Base-T



**Physical Configuration**



**Virtual Configuration**



Onboard Science  
Data Processing  
Using Flatsat

PS 12/2000



# *Many flight projects are now using Linux*



- NASA/GSFC ST-7 study
- ASRI (Australia) - JAESAT
- Hacettepe University (Turkey) - UPESAT
- JPL - Europa Orbiter
- University of Michigan (USA) - Mars Rover
- QinetiQ (UK) - STRV follow-ons
- Some International Space Station applications, on their Thinkpad laptops



## *Status*



- Agreement with SSTL to use UoSat-12 for flight code validation on a no-cost basis.
- Agreement with OMNI Project to use their UoSat-12 breadboard computer for testing, and their ground station, in exchange for continued access for IP-in-space testing.
- Preliminary build of FlightLinux running on our breadboard as of March 2001.
- Testing of FlightLinux build on UoSat-12 OBC breadboard in progress.



## *Significant Accomplishments*



- Memorandum of Understanding signed with Surrey Space Technology Laboratories (SSTL) for use of the UoSat-12 spacecraft for testing. Procurement by the Omni Project of a UoSat-12 breadboard. Co-operation with the Omni Project in use of breadboard for testing the FlightLinux product. Omni Project will also supply the HDLC synchronous serial driver for integration with FlightLinux.
- Steps for implementation and testing of FlightLinux on-orbit defined and understood.
- Specific Linux Device drivers exist
  - CAN bus, HDLC sync serial
- IP to the spacecraft works; a security approach has been defined.





# *Challenges- things to do*



- Export License issues with Flight Software
  - addressed by re-write of the SETUP code
- Communications techniques
  - Mobile IP model (in work, OMNI Project)
- Bulk Memory device driver
  - defined; write and test
- Real-time extensions to Linux
  - major flurry of activity in commercial world; wait & see



# *FlightLinux > FlightBeowulf*



- The Beowulf Software, developed at NASA/GSFC, allows low-cost clustering of computing resources.
  - Based on Linux
  - Use IP over ethernet
- Use onboard the spacecraft, to gain more computing resources than are available from a single cpu.
- Use between spacecraft to allow computation on demand.



# *Where is this all going?*



- Off this planet



# *Mars exploration*



- Becoming more routine
  - orbiters, probes, surface rovers
- Required infrastructure
  - navigation
  - communication
  - weather and event alert
- Commonality of interfaces and services
- Difficulty of the one-way comm time, and the Sun getting in the way.



# *Asteroid exploration*



- There are only 9 planets, but there are thousands of asteroids.
- A conventional survey and exploration technique takes too long.
- Need a multitude of autonomous and flexible nano-spacecraft.
- Architectural model = swarm (social insect) intelligence.
- Isn't it obvious that Linux is the base operating system?
- Low cost, low power, low weight = single chip spacecraft, with solar sails



# *FlightLinux*

## *Project Web Page*



- <http://flightlinux.gsfc.nasa.gov/>
- alternate: <http://aqua.qssmeds.com/FlightLinux>
- (.earth)